

Appl. No. 10/040,023 Atty. Doc. No. 042390.P3849 Reply to Office action 5/23/03

### AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph [006] on page 3 with the following amended paragraph.

### BRIEF DESCRIPTION OF THE DRAWINGS

[006] The drawings refer to the invention in which:

figure 1 illustrates a diagram of a prior art output buffer with pre-driver circuits;

figure 2 illustrates a block diagram of an output buffer having capacitively coupled feedback from the final output stage to the pull-up and pull-down pre-drivers;

figure 3 illustrates a simplified schematic diagram of an embodiment the pull-down portion of an output buffer having slew rate control circuitry;

figure 4 illustrates an embodiment of a transistor level schematic diagram of another pull-down portion of an output buffer having slew rate control circuitry ~~the circuit shown in figure 3;~~

figure 5 illustrates an embodiment of a cross-sectional view of a folded capacitor; and

figure 6 illustrates an embodiment of schematic of a slew rate output buffer consisting of both the pull-up and pull-down drivers.

Please replace the paragraph [0022] on page 9 with the following amended paragraph.

[0022] Figure 4 is an embodiment of a transistor level schematic diagram of another pull-down portion of an output buffer having slew rate control circuitry ~~the circuit shown in figure 3.~~ Referring to figure 4, FET refers to a field effect transistor. NFET and

Appl. No. 10/040,023 Atty. Doc. No. 042390.P3849 Reply to Office action 5/23/03

PFET refer respectively to an n-channel FET and a p-channel FET both of which are voltage controlled devices. FETs are also referred to as MOS devices or MOSFETs.

Please replace paragraph [0011] on page 5 with the following amended paragraph.

[0011] These components work together to force a controlled linear ramp on the buffer's output pad 302. Amplifier 306 feedback capacitor 308, and current mirror 314 together control the fall time of output pad 302 through pull-down transistor 304. For example, if the buffer circuit 300 connects to a bus, then the amplifier 306, feedback capacitor 308, and current mirror 314 determine just how the bus transitions voltage from a high voltage state to a low voltage state. A voltage reference is established at approximately VREF. VREF is chosen for the convenience of the particular embodiment. The node SUM is held close to the voltage reference at all times by bias circuits (not shown in figure 3). The feedback current through feedback capacitor 308 on amplifier 306 acts to keep the sum terminal (SUM) close to the voltage reference. If the voltage value of SUM is above VREF, then the amplifier drives the gate 316 of pull-down transistor 304 higher. Conversely, if voltage value of SUM is lower than VREF, amplifier 306 drives the voltage on the gate 316 lower. The higher the voltage potential on the gate 316 increases the current from PAD 302 through driver transistor 304 to ground. This increases the magnitude of the edge rate on PAD 302. In an embodiment, the gate acts as the input terminal for driver amplifier referred to as pull-down transistor 304.

Appl. No. 10/040,023 Atty. Doc. No. 042390.P3849 Reply to Office action 5/23/03

Please replace paragraph [0023] on page 9 with the following amended paragraph.

[0023] PFET 410 maybe a current source for  $i_{src}$ , controlled by voltage PBIAS1. PFET 410 sources for example, two units of current. The amplifier is a modified, folded cascode amplifier made up of NFETs 420, 418 and PFETs 412, 422. NFET 420 and PFET 412 are a current steering pair, NFETs 416, 418 make up the current sink for the amplifier. NFET 418 is controlled by voltage signal NBIAS1, and in this illustrative example, it sinks one unit of current. NFET 416 may act as a cascode for NFET 418. In an embodiment, having a positive current source and a negative current sink make the transition rate more linear throughout the entire transition range and reduces noise effects. In an embodiment, other types of current sources, with other current source or sink values or ratios, may be used as may be desired in other embodiments. The greater nominal levels of current flow minimize noise current effects and biasing the amplifier to constantly conduct allows the amplifier to operate in a linear range. NFET 416 acts as a cascode transistor to increase the effective output impedance of NFET 418, thus making its performance more like that of an ideal current source.

Please replace paragraph [0027] on page 11 with the following amended paragraph.

[0027] Three main branches of current paths exist from the output 411 of PFET 410, the current source ( $i_{src}$ ). A first current path (current sink path) exists to the current sink through PFET 412, PFET 414, NFET 416, and NFET 418. A second current path (gate current path) that passes charge to the gate of the pull-down driver transistor 404

Appl. No. 10/040,023 Atty. Doc. No. 042390.P3849 Reply to Office action 5/23/03

that passes through PFET 412, PFET 414, and to the gate of pull-down transistor 404. The third current path exists for feedback (feedback current path) current through PFET 409, PFET 413, NFET 420, feedback capacitor C 1, and the source to the drain of pull-down transistor 404. The amount of current entering current node 411, for example two units of current, equals the total current leaving current node 411 through the three main branches of current paths. The folded cascode amplifier current steers  $i_{SRC}$  through NFET 420 or PFET 412, depending on the value of  $i_{CAP\_iCAP1}$ .

Please replace paragraph [0029] on page 12 with the following amended paragraph.

[0029] When the voltage on node 424 crosses the threshold voltage of the driver transistor, pull-down NFET 404, current begins to flow between pad 402 and ground through NFET 404. This starts a negative transition on pad 402. As the voltage at pad 402 starts to decrease,  $i_{CAP\_iCAP2}$  begins to flow through capacitor C1. In an embodiment, the feedback current through capacitor C1 corresponds to equation (2). This current flow results in a lower voltage at SUM, consequently turning on NFET 420. As soon as NFET 420 is on, SUM does not go much lower and approximately all of  $i_{CAP1}$  conducts through NFET 420 and the current mirror pair 409 413. NFET 420 and the current mirror pair 409 413 drain this current from node 411, reducing the current going through PFET 412 to gate 424. The current mirror pair 409 413 multiply the amount current diverted from node 411 in proportion to the current flowing through the feedback capacitor. In an embodiment, when the slope of the signal at pad 402 is sufficient that  $i_{CAP\_iCAP2}$  is one unit (i.e., slope = target slope), then NFET 420 is

Appl. No. 10/040,023 Atty. Doc. No. 042390.P3849 Reply to Office action 5/23/03

conducting one unit, leaving only one unit to flow through PFET 412 into gate 424.

However, since NFETs 416, 418 sink one unit of current, no net current enters into gate 424. The gate voltage on pull-down transistor 404 stabilizes, thus fixing the transition rate at output pad 402.

Please replace paragraph [0030] on page 12 with the following amended paragraph.

[0030] If the slope of the signal at pad 402 exceeds the target slope, then  $i_{CAP1}$  is greater than one unit and the current through PFET 412 becomes less than one unit. This means that the net current flow into gate 424 is negative and the gate voltage on pull-down transistor 404 decreases, acting to reduce the transition slope at pad 402. This current balancing continues until the voltage at pad 402 reaches ground. At this point, the slope is forced to be zero again. No  $i_{CAP1}$  flows and all the current from PFET 410 goes to gate 424. Gate 424 starts charging again and eventually reaches substantially the voltage of  $V_{CC}$ .